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Carrier Transport in Electrical Bistable Device based on Hyperbranched Polymer and Gold Nanoparticle Composite Thin Films

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1. Introduction

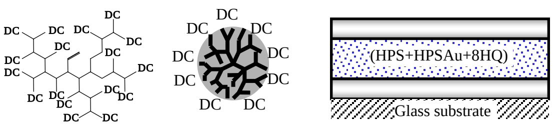
Recently, nanoparticles have been employed in organic electronic devices for various purposes. Nanoparticles have also been applied in the development of organic nonvolatile memory devices, including organic electrical bistable devices (OBDs). OBDs have two stable states of electrical conductivity at a certain voltage and these states can be switched depending on how to apply voltage. This type of OBDs is applicable as organic nonvolatile memory devices by assigning those two conduction states to "0" and "1", however, there are still many points to be comprehended about the conduction mechanism and the switching mechanism.

We have attempted to clarify these mechanisms by using such OBDs utilizing hyper-branched polymer and a metal nanoparticle. We have so far found some hints about the conduction mechanism and assumed that the aggregation and the dispersion of the nanoparticle within thin films and the change of such dispersion state affected the conduction in the OBDs deeply. From these results, we suppose that the conduction path accompanied by migration of a nanoparticle has determined the conduction in a film.

In this report, we investigated how carrier transport within a conduction path would be performed under such assumption.

2. Experimental

The device we have fabricated has single organic layer sandwiched by two aluminum electrodes, and it is the same structure as was reported in the literature.[1] The electrodes were deposited in vacuum, and the organic layer was formed by spin-coating from the solution containing hyperbranched polymer with dithiocarbamate endgroups (HPS), the gold nanoparticle which includes HPS as a dispersing agent (HPSAu), and 8-hydroxyquinoline (8HQ). The mean particle diameter of the gold in HPSAu is 2.8nm.



HPS

Fig. 1 Schematic structure of HPS and the OBD. DC indicate dithiocarbamate endgroup.

The device on the glass substrate with two 80nm thick aluminum electrodes and with 90nm organic composite film is represented as Glass/Al(80nm)/(HPS+HPSAu+8HQ) (90nm)/Al(80nm). Schematic images of HPS and structure of the device we fabricated is illustrated in Fig.1.

We observed the dependency of the current density to the temperature of the device with about 1000 ON/OFF ratio in order to clarify the carrier transport mechanism in this device. The measurements were performed at the voltage of 1.8V and in the temperature range from 70K to 300K. The temperature of the device was reduced and raised, continuously giving the voltage of 1.8V to the device, to remove the influence of the Joule's heat generated by applying voltage at the time of measurement. In addition, we investigated how current density would change with the gold content of the nanoparticle in a device for the purpose of acquiring another characteristics about a conduction mechanism. The thickness of composite film was 200nm and the content of 8HQ was 20wt% in the devices with all the gold content. All the measurement was performed in vacuum.

3. Results and discussions

Fig. 2 shows the typical current density-voltage (J-V) characteristics of our device, Glass/Al/(HPS

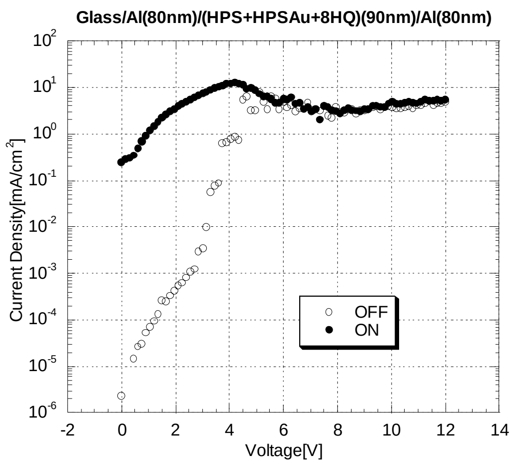


Fig. 2 Typical J-V characteristics of the OBD using HPS and HPSAu. This device shows two stable states (ON and OFF) of electrical conductivity in the voltage regions from 0V to 4V.

+HPSAu+8HQ)/Al. We assigned the high conductive state to "ON state" and the low conductive state to "OFF state", respectively.

The substrate temperature dependencies of the current densities of the device were summarized in Fig.3. The change of current density was almost the same in the procedures which raises temperature and reduces temperature. This result shows that the ON current is independent to the device temperature and the OFF current decreases according with the temperature rise. Therefore, it is suggested that the carrier transport mechanism which dominate the ON current is tunneling transport. In addition, it is supposed that OFF current was decided by metallic conduction, which may have the relationship with the gold content in the composite films.

In order to investigate about this, it was evaluated how the ON and the OFF current density would depend to the gold content in the organic composite films, respectively. We fabricated some devices with the respective gold content, and illustrated the current density of them in Fig. 4. The gold contents in composite films have been converted based on the gold content of HPSAu (6.4wt%) which was quantified by the inductively coupled plasma (ICP) measurement. Although the properties for each devices still differ greatly, this result also shows that especially OFF current is influenced by the gold content in organic films. The ON currents are also proportional to the gold content, however, that the gradient differs from the OFF current suggests a possibility of the difference in the dominant carrier transport mechanism in ON current and OFF current.

4. Conclusions

We fabricated OBDs using hyperbranched polymer and gold nanoparticle.

Since the ON current density is independent of device temperature, the tunneling transport supposed to be dominant in ON state. It is suggested that different carrier transport is dominant in an ON state and in an OFF state.

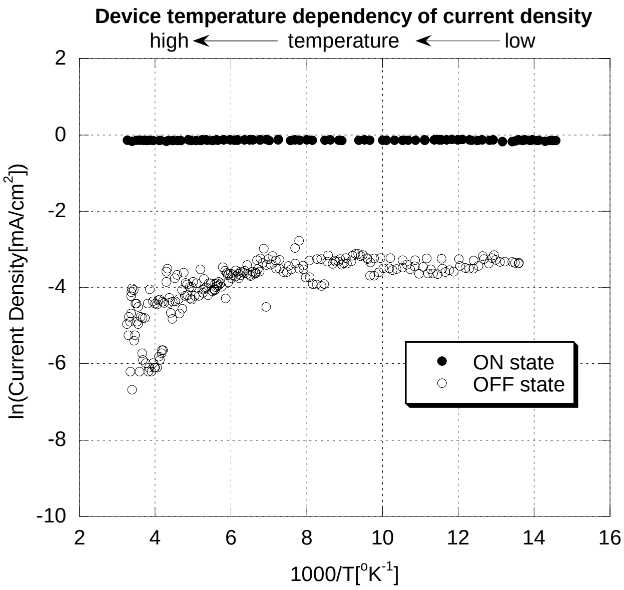


Fig. 3 The Arrhenius plot of changes of the current density accompanying the device temperature. ON state (filled circle) is independent of the device temperature.

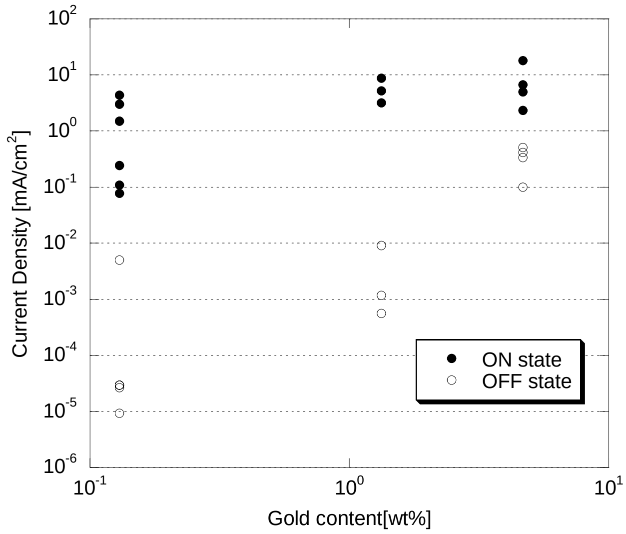


Fig. 4 The dependency of the current density on the gold content in organic composite films. Some devices were fabricated with the respective content and the ON current density and the OFF current density of them were plotted. One circle(filled and empty) exhibits ON state and the OFF state of one device.

References

[1] J. Y. Ouyang, C. W. Chu, C. R. Szmanda, L. P. Ma, and Y. Yang, *Nature Mater.*, **3** (2004) 918.

[2] H. Ichikawa, K. Yasui, M. Ozawa, and K. Fujita, *Synth. Met.*, **159** (2009) 973.